

WE CLAIM:

1 1. An estimation method for estimating illumination
2 on a sensor capable of capturing non-destructively a
3 plurality of image samples during an exposure period, said
4 method comprising the steps of:

5 measuring an illumination indication from said sensor,
6 said measuring occurs a multiplicity of times at intervals
7 during said exposure period thereby producing a
8 multiplicity of measurements; and

9 determining, based on weighted averaging, an estimated
10 illumination on said sensor from said multiplicity of
11 measurements.

1 2. The estimation method of claim 1, wherein said
2 sensor is a photodiode and said illumination indication is
3 a charge accumulated from photocurrent produced by said
4 photodiode.

1 3. The estimation method of claim 2, wherein said
2 measuring step occurring non-destructively and said charge
3 accumulating over said exposure period.

1 4. The estimation method of claim 1, wherein said
2 determining step including statistical signal processing of
3 said multiplicity of measurements, said signal processing
4 being based on a noise model selected from a fixed pattern
5 noise model, a reset noise model, a shot noise model and a
6 read noise model.

1 5. The estimation method of claim 1, wherein said
2 determining step including statistical signal processing of
3 said multiplicity of measurements, said signal processing
4 being based on maximizing a likelihood of accuracy of said
5 estimated illumination.

1 6. The estimation method of claim 1, wherein said
2 determining step including statistical signal processing of
3 said multiplicity of measurements, said signal processing
4 being based on minimizing an error of said estimated
5 illumination.

1 7. The estimation method of claim 1, wherein said
2 determining step including statistical signal processing of
3 said multiplicity of measurements, said signal processing
4 being based on minimizing a linear mean square error of
5 said estimated illumination.

1 8. The estimation method of claim 1, wherein said
2 sensor is configured in a sensor array, a pixel sensor in a
3 digital camera, a pixel sensor in a video camera, a pixel
4 sensor in a stereo digital camera or a pixel sensor in a
5 stereo video camera.

1 9. An estimation method for non-recursively
2 estimating an optimal illumination on a sensor capable of
3 capturing non-destructively a plurality of image samples
4 during an exposure period, said method comprising the
5 steps of:

6 measuring an illumination indication from said sensor;

7 storing said illumination indication, wherein said
8 measuring and storing steps occur a multiplicity of times
9 during said exposure period thereby collecting a
10 multiplicity of measurements; and
11 performing a non-recursive optimal illumination
12 estimation on said sensor from said collected multiplicity
13 of measurements.

1 10. The estimation method of claim 9, wherein said
2 determining step comprising statistical signal processing
3 of said multiplicity of measurements, said signal
4 processing being based on a noise model selected from a
5 fixed pattern noise model, a reset noise model, a shot
6 noise model and a read noise model.

1 10. The estimation method of claim 9, wherein said
2 sensor is a photodiode and said illumination indication is
3 a charge accumulated from photocurrent produced by said
4 photodiode.

1 11. The estimation method of claim 10, wherein said
2 measuring step occurring non-destructively and said charge
3 accumulating over said exposure period.

4 12. The estimation method of claim 9, wherein said
5 determining step including statistical signal processing of
6 said multiplicity of measurements, said signal processing
7 being based on maximizing a likelihood of accuracy of said
8 estimated illumination.

1 13. The estimation method of claim 9, wherein said
2 determining step further comprising statistical signal
3 processing of said multiplicity of measurements, said
4 signal processing being based on minimizing an error of
5 said estimated illumination.

1 14. The estimation method of claim 9, wherein said
2 determining step further comprising statistical signal
3 processing of said multiplicity of measurements, said
4 signal processing being based on minimizing a linear mean
5 square error of said estimated illumination.

1 15. The estimation method of claim 9, wherein said
2 sensor is configured in a sensor array, a pixel sensor in a
3 digital camera, a pixel sensor in a video camera, a pixel
4 sensor in a stereo digital camera or a pixel sensor in a
5 stereo video camera.

1 16. An estimation method for recursively estimating
2 an optimal illumination on a sensor capable of capturing
3 non-destructively a plurality of image samples during an
4 exposure period, said method comprising the steps of:

5 measuring an illumination indication from said sensor,
6 said measuring occurs a multiplicity of times at intervals
7 during said exposure period thereby producing a
8 multiplicity of measurements; and

9 determining an estimated illumination on said sensor
10 from said multiplicity of measurements, said determining
11 step occurring recursively over said multiplicity of
12 measurements and including statistical signal processing of

13 said multiplicity of measurements, said signal processing
14 being based on a noise model selected from a fixed pattern
15 noise model, a reset noise model, a shot noise model and a
16 read noise model.

1 17. The estimation method of claim 16 further
2 comprising a step of maintaining a plurality of parameters
3 during said measuring step, said plurality of parameters
4 comprising:

5 said estimated illumination;

6 means for weighting a particular one of said
7 multiplicity of measurements;

8 means for indicating variance between said particular
9 one of said multiplicity of measurements and said
10 multiplicity of measurements; and

11 means for indicating overall variance of said
12 multiplicity of measurements.

1 18. The estimation method of claim 16 further
2 comprising a step of maintaining a plurality of parameters
3 during said measuring step, said plurality of parameters
4 comprising:

5 said estimated illumination;

6 a weighting coefficient applied to a difference
7 between a present one of said multiplicity of measurements
8 and said estimated illumination corresponding to a previous
9 one of said multiplicity of measurements;

10 a mean square error of said estimated illumination;
11 and

12 a covariance of said estimated illumination with said
13 present one of said multiplicity of measurements.

1 19. The estimation method of claim 16, wherein said
2 sensor is a photodiode and said illumination indication is
3 a charge accumulated from photocurrent produced by said
4 photodiode.

1 20. The estimation method of claim 16, wherein said
2 measuring step occurring non-destructively and said charge
3 accumulating over said exposure period.

4 21. The estimation method of claim 16, wherein said
5 determining step including statistical signal processing of
6 said multiplicity of measurements, said signal processing
7 being based on maximizing a likelihood of accuracy of said
8 estimated illumination.

1 22. The estimation method of claim 16, wherein said
2 determining step further comprising statistical signal
3 processing of said multiplicity of measurements, said
4 signal processing being based on minimizing an error of
5 said estimated illumination.

1 23. The estimation method of claim 16, wherein said
2 determining step further comprising statistical signal
3 processing of said multiplicity of measurements, said
4 signal processing being based on minimizing a linear mean
5 square error of said estimated illumination.

1 24. The estimation method of claim 16, wherein said
2 sensor is configured in a sensor array, a pixel sensor in a
3 digital camera, a pixel sensor in a video camera, a pixel
4 sensor in a stereo digital camera or a pixel sensor in a
5 stereo video camera.

1 25. An apparatus configured to estimate illumination
2 on a sensor during an exposure period, said apparatus
3 comprising:

4 a sampling means configured to measure, at a
5 multiplicity of time intervals during said exposure period,
6 an illumination indication from a sensor, and configured to
7 thereby produce a multiplicity of measurements; and

8 an estimation means configured to determine, based on
9 weighted averaging, an estimated illumination on said
10 sensor from said multiplicity of measurements.

1 26. The apparatus of claim 25, wherein said sensor is
2 implemented in a sensor array, a pixel sensor in a single
3 chip imaging device, a pixel sensor in a digital camera, a
4 pixel sensor in a video camera, a pixel sensor in a stereo
5 digital camera or a pixel sensor in a stereo video camera.

1 27. The apparatus of claim 25, wherein said sensor is
2 a photodiode and said illumination indication is a charge
3 accumulated from photocurrent produced by said photodiode.

1 28. The apparatus of claim 27, wherein said sampling
2 means operates non-destructively and said charge
3 accumulates over said exposure period.

1 29. The apparatus of claim 25, wherein said
2 estimation means being configured to perform statistical
3 signal processing of said multiplicity of measurements,
4 said signal processing being based on a noise model
5 selected from a fixed pattern noise model, a reset noise
6 model, a shot noise model and a read noise model.

1 30. The apparatus of claim 25, wherein said
2 estimation means being configured to perform statistical
3 signal processing of said multiplicity of measurements,
4 said signal processing being based on maximizing a
5 likelihood of accuracy of said estimated illumination.

1 31. The apparatus of claim 25, wherein said
2 estimation means being configured to perform statistical
3 signal processing of said multiplicity of measurements,
4 said signal processing being based on minimizing an error
5 of said estimated illumination.

1 32. The apparatus of claim 25, wherein said
2 estimation means being configured to perform statistical
3 signal processing of said multiplicity of measurements,
4 said signal processing being based on minimizing a linear
5 mean square error of said estimated illumination.

1 33. An apparatus configured to estimate illumination
2 on a sensor during an exposure period, said apparatus
3 comprising:

4 a sampling means configured to measure, at a
5 multiplicity of time intervals during said exposure period,
6 an illumination indication from a sensor, and configured to
7 thereby produce a multiplicity of measurements; and
8 an estimation means configured to determine an
9 estimated illumination on said sensor from said
10 multiplicity of measurements, said estimation means being
11 configured to compute recursively over said multiplicity of
12 measurements and to maintain recursively a plurality of
13 parameters over said multiplicity of measurements, said
14 plurality of parameters comprising:
15 said estimated illumination;
16 means for weighting a particular one of said
17 multiplicity of measurements;
18 means for indicating variance between said particular
19 one of said multiplicity of measurements and said
20 multiplicity of measurements; and
21 means for indicating overall variance of said
22 multiplicity of measurements.

1 34. An apparatus configured to estimate illumination
2 on a sensor during an exposure period, said apparatus
3 comprising:
4 a sampling means configured to measure, at a
5 multiplicity of time intervals during said exposure period,
6 an illumination indication from a sensor, and configured to
7 thereby produce a multiplicity of measurements; and
8 an estimation means configured to determine an
9 estimated illumination on said sensor from said
10 multiplicity of measurements, wherein said estimation means

11 being configured to perform statistical signal processing
12 of said multiplicity of measurements, said signal
13 processing being based on a noise model selected from a
14 fixed pattern noise model, a reset noise model, a shot
15 noise model and a read noise model, and wherein said
16 estimation means being configured to compute recursively
17 over said multiplicity of measurements and to maintain
18 recursively a plurality of parameters over said
19 multiplicity of measurements, said plurality of parameters
20 comprising:

21 said estimated illumination;
22 a weighting coefficient applied to a difference
23 between a present one of said multiplicity of measurements
24 and said estimated illumination corresponding to a previous
25 one of said multiplicity of measurements;
26 a mean square error of said estimated illumination;
27 and
28 a covariance of said estimated illumination with said
29 present one of said multiplicity of measurements.

1 35. An apparatus configured to estimate illumination
2 on a sensor during an exposure period for simultaneously
3 reducing noise and improving dynamic range at low
4 illumination end, where said sensor is configured in a
5 complementary metal oxide semiconductor (CMOS) image sensor
6 system capable of capturing multiple image samples during
7 said exposure period, said apparatus comprising:
8 means for measuring, at a multiplicity of intervals
9 during said exposure period, actual photocurrent from said

10 sensor, said means for measuring thereby producing a
11 multiplicity of photocurrent measurements; and
12 means for estimating optimal photocurrent on said
13 sensor from said multiplicity of measurements.

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